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BUREAU OF MINES MINERALS YEARBOOK

Abrasive Materials

UNITED STATES DEPARTMENT OF THE INTERIOR

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Abrasive Materials

By Gordon T. Austin[1]

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The combined production value of natural abrasives, which consist of tripoli, special silica stone, garnet, staurolite, and emery, increased in 1987. The increase was, in certain cases, because the materials were used in nonabrasive applications, such as the increased use of tripoli as a filler and special silica stone material as a special-purpose crushed stone. The increased use of garnet as a blasting media accounts for most of its growth. Production and sales of garnet were at a record-high level in 1987.

Table 1.—Salient U.S. abrasives statistics

		1983	1984	1985	1986	1987
Natural abrasives production by producers:						
Tripoli (crude)	short tons	111,020	124,482	W	117,174	114,926
Value	thousands	$649	$699	W	$918	$975
Special silica stone[1]	short tons	1,101	1,290	1,157	1,073	12,773
Value	thousands	$482	$602	$515	$501	$957
Garnet[2]	short tons	29,767	29,647	36,727	32,296	42,277
Value	thousands	$2,533	$2,487	$2,973	$2,603	$4,350
Emery	short tons	W	W	W	2,878	1,945
Value	thousands	W	W	W	W	W
Staurolite		W	W	W	W	W
Value	thousands	W	W	W	W	W
Manufactured abrasives[3] [e]	short tons	418,153	531,264	478,897	482,860	486,442
Value[4]	thousands	$167,430	$203,231	$171,974	$173,858	$182,039
Foreign trade (natural and artificial abrasives):						
Exports (value)[5]	do	$192,794	$191,003	$191,272	$207,624	$238,522
Reexports (value)[5]	do	$24,111	$27,248	$23,845	[r]$27,011	$21,192
Imports for consumption (value)[5]	do	$289,865	$381,694	$382,877	[r]$406,572	$424,640

[r]Revised. W Withheld to avoid disclosing company proprietary data.
[1]Includes grindstones, oilstones, whetstones, and deburring media. Excludes grinding pebbles and tube-mill liners.
[2]Primary garnet; denotes first marketable product.
[3]Includes Canadian production of crude silicon carbide and fused aluminum oxide and shipments of metallic abrasives by producers.
[4]Excludes United States and Canadian production and value of aluminum zirconium oxide.
[5]Bureau of the Census.

Sales of special silica stone finished products, grinding stones, oilstones, whetstones, and deburring media, suffered from declining domestic and foreign markets. Manufactured abrasive products are displacing the natural abrasive in many of the traditional sharpening and grinding areas. The significant increase in production of crude silica stone indicated in table 1 is the result of a change in the method of reporting production of crude, not a change in actual production.

The nonmetallic manufactured abrasives industry, which includes only silicon carbide and fused aluminum oxide in the reported statistics, continued to decline in quantity of material produced for the second year. However, the value of production increased because of an increase in the average unit value of the materials produced. Production trends for the last 3 years showed an increase in the amount of silicon carbide produced and a decrease in the amount of fused aluminum oxide produced.

The metallic abrasives industry, which includes the primary producers of steel shot and grit, chilled and annealed iron shot and grit, cut wire shot, and shot and grit, reclaimed by primary manufacturers, experienced the third year of sales recovery in both quantity and value. Sales are still approximately 18% below the 10-year high of 264,135 short tons in 1979.

The United States continued as the world's largest single manufacturer, exporter, and consumer of synthetic industrial diamond. The estimated apparent U.S. consumption of industrial diamond was 72.8 million carats of all types and classes.

Domestic Data Coverage.—Domestic production data for abrasive materials are developed by the Bureau of Mines from six separate, voluntary surveys. Of the 61 operations canvassed, producing natural and manufactured abrasives, all responded, representing 100% of the total production shown in tables 1, 5, 6, 8, 15, 16, and 17.

FOREIGN TRADE

Exports plus reexports of industrial diamonds continued at record-high levels. Exports plus reexports have increased every year for the past 10 years, with the exception of the essentially constant levels of 1985 and 1986. The total exports of industrial diamonds have grown approximately 175% in the past 10 years or at a compounded average rate of approximately 11% per year.

The total value of abrasive materials, exports plus reexports, was $251.9 million in 1987. The average total value for the last 10 years was $222.2 million per year with the high in 1979 of $278.4 million and the low in 1977 of $156.9 million. The last 2 years have shown significant increases in total value compared with the essentially level years 1983-85. The United States was a net exporter of industrial diamonds in 1987.

Industrial diamond imports were at a record high 48.9 million carats of loose material. This was an increase of 6% after 2 years of essentially level imports. However, the growth is significant in view of the approximately 76% increase in imports from 1983 to 1984.

Imports of industrial diamond stones were at the lowest level since 1939. The Republic of South Africa supplied 42% of the industrial stones imported into the United States in 1986, but furnished only about 4% of the 1987 imports. The Republic of South Africa's share of total U.S. imports of industrial diamonds dropped to about 0.3% in 1987 from 9% in 1986. The major sources of imports, in order of rank, were Ireland, Japan, Zaire, Belgium-Luxembourg, and the U.S.S.R. Total imports continued to increase for the fifth consecutive year and established a record value of $418.4 million. This resulted in an abrasive materials trade deficit of $166.5 million.

Table 2.—U.S. exports of abrasive materials, by kind

(Thousands)

Kind		1986		1987	
		Quantity	Value	Quantity	Value
NATURAL					
Industrial diamond, natural or synthetic, powder or dust	carats	46,839	$83,853	55,003	$88,710
Industrial diamond, natural or synthetic, other	do.	1,669	10,444	1,004	12,164
Emery, natural corundum, pumice in blocks	pounds	2,374	1,061	3,092	1,069
MANUFACTURED					
Artificial corundum (fused aluminum oxide)	do.	21,836	18,963	28,017	22,298
Silicon carbide, crude or in grains	do.	8,386	7,110	10,505	7,819
Carbide abrasives, n.e.c.	do.	327	509	426	491
Other refined abrasives	do.	23,896	14,287	31,435	19,417
Grinding and polishing wheels and stones:					
Diamond	carats	451	5,358	489	5,793
Polishing stones, whetstones, oilstones, hones, similar stone	number	1,086	2,416	1,020	2,009
Wheels and stones, n.e.c.	pounds	4,459	21,295	5,640	25,876
Abrasive paper and cloth, coated with natural or artificial abrasive materials	do.	11,455	36,365	16,508	46,007
Grit and shot including wire pellets	do.	13,964	5,963	15,967	6,869
Total		XX	207,624	XX	238,522

XX Not applicable.

Source: Bureau of the Census.

Table 3.—U.S. reexports of abrasive materials, by kind

(Thousands)

Kind		1986		1987	
		Quantity	Value	Quantity	Value
NATURAL					
Industrial diamond, natural or synthetic, powder or dust	carats	4,324	$5,959	1,789	$4,148
Industrial diamond, natural or synthetic, other	do.	1,895	19,869	1,538	15,428
Emery, natural corundum, pumice in blocks	pounds	145	264	258	156
MANUFACTURED					
Artificial corundum (fused aluminum oxide)	do.	23	17	181	135
Silicon carbide, crude or in grains	do.	122	87	2	6
Grinding and polishing wheels and stones:					
Diamond	carats	13	239	4	171
Polishing stones, whetstones, oilstones, hones, similar stone	number	4	2	3	10
Wheels and stones, n.e.c.	pounds	111	453	214	847
Abrasive paper and cloth, coated with natural or artificial abrasive materials	do.	90	121	133	291
Total		XX	r27,011	XX	21,192

rRevised. XX Not applicable.

Source: Bureau of the Census.

Table 4.—U.S. imports for consumption of abrasive materials (natural and artificial), by kind

(Thousands)

Kind		1986		1987	
		Quantity	Value	Quantity	Value
Emery, flint, rottenstone, tripoli, crude or crushed	short tons	3	$2,187	8	$451
Silicon carbide, crude	do.	76	30,946	84	35,603
Aluminum oxide, crude	do.	142	55,884	142	58,541
Other crude artificial abrasives	do.	7	719	3	704
Abrasives, ground grains, pulverized or refined:					
Silicon carbide	do.	7	10,558	9	11,566
Aluminum oxide	do.	17	13,805	17	16,103
Emery, corundum, flint, garnet, other, including artificial abrasives	do.	2	7,330	4	9,471
Papers, cloths, other materials wholly or partly coated with natural or artificial abrasives		(1)	106,704	(1)	117,208
Hones, whetstones, oilstones, polishing stones	number	3,147	1,745	1,483	1,362
Abrasive wheels and millstones:					
Burrstones manufactured or bound up into millstones	short tons	(2)	20	1	129
Solid natural stone wheels	number	816	550	773	489
Diamond	do.	807	10,553	414	12,685
Abrasive wheels bonded with resins	pounds	10,733	19,642	11,147	21,711
Other		(1)	18,829	(1)	20,777
Articles not specifically provided for:					
Emery or garnet		(1)	327	(1)	708
Natural corundum or artificial abrasive materials		(1)	10,251	(1)	12,319
Other n.s.p.f.		(1)	4,275	(1)	5,275
Grit and shot, including wire pellets	pounds	6,767	1,799	5,950	2,236
Diamond, natural and synthetic:					
Diamond dies	number	13	700	53	1,767
Crushing bort	carats	252	338	327	408
Natural industrial diamond stones	do.	8,436	61,808	3,322	34,771
Miners' diamond	do.	472	2,645	[3]551	3,166
Powder and dust, synthetic	do.	29,570	38,018	[4]32,060	43,901
Powder and dust, natural	do.	7,261	7,839	12,677	13,289
Total		XX	r406,572	XX	424,640

rRevised. XX Not applicable.
[1]Quantity not reported.
[2]Less than 1/2 unit.
[3]Includes 74,077 carats of synthetic miners' diamond.
[4]Includes 403,977 carats of other synthetic diamonds.

Source: Bureau of the Census.

TRIPOLI

Fine-grained, porous silica materials are grouped together under the category tripoli because they have similar properties and end uses. Processed tripoli, sold or used, decreased slightly in quantity but increased 6% in value. The value increased 15% for filler material, but for the third consecutive year, decreased slightly for abrasive material.

Because tripoli grains lack distinct edges and corners, they were used as mild abrasives in toothpaste and toothpolishing compounds, industrial soaps, metal and jewelry polishing compounds, and as buffing and polishing compounds in lacquer finishing in the automobile industry. The mineral also was used as a filler and extender in paint, plastic, rubber, and enamels.

The six firms producing tripoli were Malvern Minerals Co., Garland County, AR, which produced crude and finished material; American Tripoli Co., which produced crude material in Ottawa County, OK, and finished material in Newton County, MO; Illinois Minerals Co. and Tammsco Inc., both in Alexander County, IL, which produced crude and finished amorphous (microcrystalline) silica; and Keystone Filler and Manufacturing Co. in Northumberland County, PA, which processed rottenstone, a decomposed fine-grained siliceous shale produced by B. J. Ulrich & Sons, also in Northumberland County, PA.

Tripoli, paper bags, carload in cents per pound	
White, Elco, IL:	
Air floated through 200 mesh	3.55
Rose and cream, f.o.b. Seneca, MO, and Rogers, AR:	
Once ground	2.90
Double ground	2.90
Air float	3.15
Amorphous silica, 50-pound, bags, f.o.b. St. Louis, IL, in dollars per short ton:	
Through 200 mesh:	
90% to 95%	$71.00
96% to 99%	72.00
98% to 99.4%	78.00
99.5%	95.00
99.9% passing 400 mesh	128.00
99% below 15 micrometers	137.00
99% below 10 micrometers	164.00
99% below 8 micrometers	196.00

Table 5.—Processed tripoli[1] sold or used by producers in the United States, by use[2]

Use		1983	1984	1985	1986	1987
Abrasives	short tons	38,073	40,812	40,022	36,584	29,362
Value	thousands	$3,203	$3,738	$3,670	$3,590	$3,089
Filler	short tons	65,138	65,941	68,800	73,908	78,440
Value	thousands	$6,077	$6,989	$6,452	$8,588	$9,855
Other	short tons				W	W
Value	thousands				W	W
Total	short tons	103,211	106,753	108,822	110,492	107,802
Total value	thousands	$9,280	$10,727	$10,122	$12,178	$12,944

W Withheld to avoid disclosing company proprietary data.
[1]Includes amorphous silica and Pennsylvania rottenstone.
[2]Partly estimated.

SPECIAL SILICA STONE PRODUCTS

Production of special silica stone products included oilstones, hones, and whetstones from Arkansas and Indiana, grindstones from Ohio, and deburring media from Arkansas and Wisconsin. Production of special silica stone products dropped, due in large part to displacement in the traditional whetstone, hone, and grindstone markets by manufactured abrasives, industrial diamond, and ceramics.

Four main grades of whetstone were produced, ranging from the high-quality Black Hard Arkansas Stone, with porosity of 0.07% and characterized by a waxy luster, down to the Washita Stone, with a porosity of 16% and resembling unglazed porcelain. The four main types were as follows:

Trade name	Use
Black Hard Arkansas Stone	Polishing the most perfect edge possible.
Hard Arkansas Stone	Polishing blades to a very fine edge.
Soft Arkansas Stone	General purpose.
Washita Stone	Rapid sharpening.

Table 6.—Special silica stone finished products sold or used in the United States[1]

Year	Quantity (short tons)	Value (thousands)
1983	602	$3,814
1984	683	3,975
1985	443	1,452
1986	437	4,771
1987	220	2,159

[1]Includes grindstones, oilstones, and whetstones. Excludes grinding pebbles and tube-mill liners, and deburring media.

Table 7.—Producers of special silica stone products in 1987

Company and location	Type of operation	Product
Arkansas Oilstone Co.: Hot Springs, AR (inactive)	Stone cutting and finishing	Whetstones and oilstones.
Arkansas Whetstone Co. Inc.:		
Hot Springs, AR	do	Do.
Do	Quarry	Crude novaculite.
Beraboo Quartzite Co. Inc.:		
Baraboo, WI	Crushing and sizing	Deburring media.
Do	Quarry	Crude silica stone.
Buffalo Stone Corp.: Hot Springs, AR	Tumbling and sizing novaculite.	Metal finishing media and deburring media.
Cleveland Quarries Co.:		
Amherst, OH	Stone cutting and finishing	Grindstones.
Do	Quarry	Crude silica stone.
Dans Whetstone Cutting Co. Inc.:		
Royal, AR	Stone cutting and finishing	Whetstones and oilstones.
Do	Quarry	Crude novaculite.
Halls Arkansas Oilstones Inc.: Pearcy, AR	Stone cutting and finishing	Whetstones and oilstones.
Hindostan Whetstone Co.:		
Bedford, IN	do	Cuticle stones.
Do	Quarry	Crude silica stone.
Hiram A. Smith Whetstone Co. Inc.:		
Hot Springs, AR	Stone cutting and finishing	Whetstones and oilstones.
Do	Quarry	Crude novaculite.
Norton Co. Oilstones, Norton Pike Div.:		
Hot Springs, AR	do	Do.
Littleton, NH	Stone cutting and finishing	Whetstones and oilstones.
Pioneer Whetstone Co.: Hot Springs, AR	do	Do.
Poor Boy Whetstones: Hot Springs, AR (inactive)	do	Do.
Robert Lowery: Hot Springs, AR	do	Do.
Taylor Made Crafts Inc.: Lake Hamilton, AR	do	Do.
Wallis Whetstone Inc.:		
Malvern, AR	do	Do.
Do	Quarry	Crude novaculite.
Washita Mountain Whetstone Co.: Lake Hamilton, AR	Stone cutting and finishing	Whetstones and oilstones.

Arkansas accounted for 76% of the value and 88% of the total quantity of special silica stone products sold or used by U.S. producers.

GARNET

The United States continued to be the largest garnet producer and consumer, accounting for about 63% of the world's production; the remainder was produced primarily, in order of size, by India, Australia, China, and the U.S.S.R. A major garnet processing complex was under construction at yearend in Norway. Four domestic producers were active in 1987, two in New York and one each in Idaho and Maine. Barton Mines Corp., Warren County, NY, produced garnet for use in coated abrasives, glass grinding and polishing, and metal lapping. The NYCO Div. of Processed Minerals Inc., Essex County, NY, reported that crude garnet concentrate was recovered as a byproduct at its Wollastonite operation and was sold to a U.S. garnet producer for refinement and sales. Emerald Creek Garnet Milling Co. continued to operate two mines and a single mill in Benewah County, ID, and reported that its garnet was used chiefly in sandblasting and water filtration. Industrial Garnet Extractives Inc., near Rangeley in Oxford County, ME, produced a range of garnet products, which were used mostly in sandblasting and water filtration. At yearend, International Garnet Abrasives had completed construction and began startup procedures for a 10,000-ton-per-year facility to reclaim garnet near Harvey, LA. Commercial operation is planned for 1988.

Production of crude garnet concentrates increased 31% in quantity and 67% in value. The quantity of refined garnet sold or used increased 24% and the value increased about 15% compared with that of 1986. The quantities and values in both crude and refined garnets were record highs.

Table 8.—Garnet sold or used by producers in the United States

Year	Quantity (short tons)	Value (thousands)
1983	30,300	$5,970
1984	27,672	5,677
1985	30,634	6,102
1986	31,856	6,748
1987	39,476	7,744

EMERY

One company, John Leardi Emery Mine, continued to produce emery from a mine near Peekskill in Westchester County, NY. The crude material, an impure corundum containing magnesium-aluminum silicates, was processed by Washington Mills Abrasives Co., North Grafton, MA, and Emeri-Crete Inc., New Castle, NH. Domestic emery was used as an abrasive aggregate for nonskid, wear-resistant floors, pavements, and stair treads. Minor uses of domestic emery were as coated abrasives and tumbling or deburring media.

World production of emery was primarily from Turkey and Greece. In 1987, production of emery in Turkey was reported as 10,391 short tons, and production in 1986 in Greece was reported to be 8,267 short tons. General Abrasives Co. imported emery from Turkey and Greece, processed it at its Westfield, MA, facility, and distributed the product.

STAUROLITE

Staurolite is a naturally occurring, complex, hydrated aluminosilicate of iron having a variable composition. The mineral most commonly occurs as opaque reddish-brown to black crystals with specific gravity ranging from 3.74 to 3.83 and Mohs' hardness between 7 and 8.

A limited rock-shop trade in cruciform twinned staurolite crystals ("fairy crosses") exists, notably from deposits in Georgia, North Carolina, and Virginia. Staurolite was produced commercially in 1987 by E. I. du Pont de Nemours & Co. Inc.

Staurolite is a byproduct of heavy-mineral concentrates recovered from a glacial-age beach sand in Clay County, north-central Florida. The staurolite is removed by electrical and magnetic separation after the concentrates have been scrubbed and chemically washed with caustic, rinsed, and dried. The resulting material is comprised of about 77% clean, rounded, and uniformly sized grains of staurolite, with minor proportions of tourmaline, ilmenite and other titanium minerals, kyanite, zircon, and quartz. A nominal composition of this staurolite sand is 45% aluminum oxide (minimum), 18% ferric oxide (maximum), 5% silica (maximum), and 3% zirconium dioxide (maximum).

Although originally marketed only as an ingredient in some portland cement formulations, staurolite is now marketed as a specialty sand under the trade name Biasill for use as molding material in nonferrous foundries, owing to its low thermal expansion, high thermal conductivity, and high melting point. Its low softening point tends to restrict it to nonferrous casting. Its major use is as an abrasive for impact finishing of metals and sandblasting of buildings under the trade names Starblast (80 mesh) and Biasill (90 mesh). A coarse grade (55 mesh) is also used as an abrasive.

Quantitative production data are withheld from publication to avoid disclosing company proprietary data, but the 1987 production of staurolite decreased 25% from that of 1986; shipments increased 14% in tonnage and 24% in value. Domestic production capacity was slightly under 100,000 tons per year because only one of two producers operated in 1987, and because that producer made a higher purity product, which increased processing losses. The purified product was created in response to the need to lower the free silica content of staurolite used for sandblasting to reduce the risk of silicosis caused by free silica dust.

Staurolite continued to be produced in India in small quantities and sometimes by other nations as well. A significant deposit of staurolite was discovered 125 miles north of Toronto, Canada. The deposit is in a pelite schist and is about 1.5 miles long and 130 feet wide. The material graded 10% magnetite, 25% staurolite, and 5% garnet.

INDUSTRIAL DIAMOND

The four domestic firms that produced synthetic industrial diamond in 1987 were DuPont Industrial Diamond Div., Gibbstown, NJ; General Electric Co. (GE), Specialty Materials Department, Worthington, OH; Megadiamond Industries Inc., a subsidiary of Smith International Inc., Provo, UT; and Valdiamant International, a division of Valeron Corp., Ann Arbor, MI. During 1987, GE purchased Valdiamant's manufacturing facilities and closed and disassembled them. Secondary production of industrial diamond, as reclaimed from used drill bits, diamond tools, and wet and dry diamond-containing waste, was estimated to be 3.3 million carats.

The National Defense Stockpile of industrial diamonds, as of December 31, 1987, was 22 million carats of crushing bort; however, the 8.5 million carats of stones exceeded the proposed goal of 7.7 million carats. Available for disposal, from enabling legislation effective October 1, 1984, was 0.8 million carats of stone. The inventory of small diamond dies was 25,473 pieces, compared with a goal of 60,000 pieces; however, no purchase authorization was issued. Certain industrial diamond stones in excess of stockpile goals were sold during 1987 to support the program to upgrade ferroalloys.

Exports plus reexports of industrial diamond dust and powder, natural and synthetic, were a record high 56.8 million carats, and the value was a record high $92.9 million. Exports plus reexports of stone totaled 2.5 million carats valued at $27.6 million.

The United States remained the largest consumer of industrial diamond. Apparent consumption of natural and synthetic grit, dust, and powder was estimated to be 70.9 million carats, and apparent consumption of natural stones was estimated to be 1.3 million carats. This was the lowest apparent consumption of industrial stones in 48 years.

WORLD REVIEW

De Beers Consolidated Mines Ltd.'s sales of uncut diamonds through the Central Selling Organization in 1987 were reported to be a record high $3.07 billion compared with $2.56 billion in 1986, an increase of approximately 20%.

Angola.—Sociedade Portuguesa de Empreendimentas and Endeama (SPE), a Portuguese company, signed a 2-year agreement with the Angolan state mining company to mine and appraise diamonds. SPE will also assist in diamond exploration and training Angolan personnel.[2] Angolan diamond production continues to suffer because of the civil war.

Australia.—Argyle Diamond Mines Joint Venture completed the second year of production from the AK-1 lamproite pipe. Production of 30.3 million carats exceeded the planned production of 25 million carats. Additionally, Argyle formed a direct relationship with the Indian diamond cutting trade to upgrade its diamond cutting technology to reduce the amount of Argyle near gem material that is reclassified as industrial because of cutting difficulties.[3]

Freeport Bow River Properties Inc., the operating company of the Freeport-McMoRan Australia Ltd. and Gem Exploration and Minerals Ltd. joint venture, started construction of the Bow River alluvial diamond project. The project will process 4,000 metric tons per day of gravel. Diamond output is expected to exceed 600,000 carats per year. The diamond production is expected to be 18% to 25% gem quality, 65% to 72% near gem quality, and 8% to 10% bort.

Botswana.—Debswana, the Botswana diamond mining company that is a 50-50 joint venture between De Beers and the Government of Botswana, sold its significant diamond stockpile to De Beers for cash and newly issued De Beers shares. The stockpile was estimated to contain a high proportion of large, high-quality gem material. The Government of Botswana now owns 2.6% of De Beers and has the right to appoint two members to the board of directors of De Beers and the De Beers Diamond Trading Co.[4]

Brazil.—Mining and production started on a diamond-rich kimberlite pipe in the State of Mato Grosso, approximately 20 kilometers from Julina. This is the first production from a kimberlite pipe in Brazil. All production to date was from secondary alluvial sources.

Canada.—Dia Met Minerals of Vancouver continued to negotiate financing for drilling the Jack Kimberlite Pipe in British Columbia. The pipe, 55 kilometers north of Golden, British Columbia, contains minute gem-quality diamonds. The company sampled additional pipes in the area during the summer months. Information from the summer program is not available at this time.

Central African Republic.—African Star Mining Co., a subsidiary of the U.S. firm O'Hara Mining and Drilling Co., established the first large-scale mechanized diamond mining operation in the Central African

Republic. Two mines and associated washing plants, with an initial production rate of 2,500 cubic meters per day, were under construction with production to begin in early 1988. Annual production is expected to be approximately 670,000 carats per year, 200% of the current total production of the Central African Republic.

China.—Boarara Mining Ltd. of Australia entered into an agreement with Southolme Ltd. of Hong Kong to explore and develop diamond projects in Hunan Province in China. Diamonds are found along the 1,000-kilometer length of the Yuan Jiang River terraces and channels, which are often 20 to 30 meters deep and up to 300 to 400 meters wide. The terraces have been mined for years by local farmers. A source pipe for the diamonds has not been found.

The Yuan Jiang River Alluvial Project, a joint venture between City Resources (Asia) Ltd. (a subsidiary of the Australian company, City Resource Ltd.), China Hunan International Development Corp. and China Geology Import and Export Group, was formed to explore for and produce diamonds and gold on the lower reaches of the Yuan Jiang River. City Resources will supervise and control the work, and the Chinese partners will furnish the labor force. The project area is approximately 120 square kilometers.

Indonesia.—Acorn Securities Ltd. continued negotiations with the Government of Indonesia for a long-term production agreement for the Southeast Kalimantan diamond project. The first parcel of diamonds from the project, 1,032 carats, was evaluated at an average value of $170 per carat. The parcel of 6,342 stones was 97% gem quality. Acorn has a reserve base of 16 million cubic meters with an average grade of 0.2 carats of diamond, 80 milligrams of gold, and 20 milligrams of platinum per cubic meter.

Sierra Leone.—Diamond Corp. a subsidiary of De Beers, negotiated with the Government of Sierra Leone regarding a $3 million loan to rehabilitate the mining equipment for the National Diamond Mining Co.'s operations at Yengema.[5] Oliver Resources PLC, through its Sierra Leone subsidiary, was granted exclusive gold and diamond licenses on about 78 square kilometers of alluvial deposits along tributaries of the Pampana River.

South Africa, Republic of.—Thirteen additional marine diamond concessions were allocated off the South African west coast. Fourteen companies or individuals are working the concessions that were issued in 1983-84. The 1987 marine diamond production was estimated at 55,000 carats. De Beers began procedures to reactivate the Koffiefontein Mine in the Orange Free State. The mine, idle since 1982, is expected to be back in production in early 1988.

TECHNOLOGY

A British firm developed a polycrystalline diamond (PCD) tipped sawblade for cutting melamine PVC and Formica-faced chipboard used in the manufacture of furniture. The PCD tipped blades replaced carbide tipped blades, which had to be sharpened every 3 to 4 hours. The PCD was used continuously for 6 months before a regrind was necessary.[6]

A British manufacturer of ironing boards made from chipboard was using a tungsten-carbide tooled profiling router. The tungsten-carbide cutter had a life between regrinds of 150 boards. The tungsten-carbide tools were replaced by Syndite PCD tooling resulting in a 98% savings in manufacturing cost per board by increasing the regrind intervals from 150 boards to 30,000 boards.[7]

Pennsylvania State University developed a method for depositing diamond-type coatings on silicon and other materials. The diamond coatings' electric- and heat-conducting properties are suitable for coating computer chips. The diamond coatings, created by passing methane and hydrogen through a microwave plasma, were chemically and structurally identical to natural diamond.[8]

A U.S. firm developed a thermally stable, continuously self-sharpening PCD compact for implanting into drill bits. Comparison tests between drill bits using the PCD compacts and natural diamonds demonstrated that the PCD compacts averaged 57% higher penetration rates, 277% longer bit life, and reduced bit costs to $6.35 per foot as opposed to $11.00 per foot.[9]

Table 9.—U.S. imports for consumption of industrial diamond (excluding diamond dies)

(Thousand carats and thousand dollars)

Year	Quantity	Value
1983	24,877	88,617
1984	43,710	113,632
1985	46,222	127,191
1986	45,991	110,648
1987	48,577	95,559

Table 10.—U.S. imports for consumption of industrial diamond, by country[1]

(Thousand carats and thousand dollars[2])

Country	Natural industrial diamond stones (including glaziers' and engravers' diamond, uncut) (520.2900)[3]				Miners' diamond Natural and synthetic[4] (520.1900 and 520.2340)[3]				Diamond powder and dust, synthetic (520.2000, 520.2020, 520.2040, 520.2060, 520.2100)[3]				Diamond powder and dust, natural (520.2900)[3]			
	1986		1987		1986		1987		1986		1987		1986		1987	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
Australia	72	154	9	114					11	10					4	47
Belgium-Luxembourg	979	8,132	553	4,653	20	281	33	423	330	853	459	763	1,084	801	703	833
Canada	71	121	2	166			(5)	4	38	36	70	59	1,118	1,904	208	89
China	4	6	(5)	13							23	42			6	325
Congo	8	22	2	58												
Finland															43	78
France	2	85	(5)	16	12	18	18	57	40	12	30	9			1	2
Germany, Federal Republic of	1	49	42	490	23	102	13	180	181	251	1,044	379	174	344	108	260
Ghana	71	232	156	1,826											794	889
Greece									857	446	525	240				
Hong Kong	6	142	2	66			1	51			(5)	11			(5)	1
Iran	247	165	20	69	5	12	86	313	82	173						
Ireland	330	1,199	201	924	113	727	154	1,011	21,205	32,351	22,751	37,925	982	1,369	4,038	3,253
Israel	139	190	6	303	3	11			148	56	45	84	55	54	(5)	24
Italy	99	28			(5)	15			337	109	361	226	3	48	25	51
Japan	46	1,462	14	614					4,281	2,119	4,694	3,000	1,316	419	1,465	620
Mexico	10	84							1	5			1	1		
Netherlands	151	1,191	60	642			1	9				12	19	139		
South Africa, Republic of	3,556	37,622	131	1,539	5	5	1	18	64	194			611	382	7	112
Switzerland	20	793	4	326					426	379	299	148	461	581	210	175
U.S.S.R.			1	68					62	17	291	102			1,206	372
United Kingdom	1,975	6,418	806	14,594	89	378	40	135	1,136	609	367	308	923	1,018	844	1,984
Venezuela	8	978					(5)	6	(5)	3						
Zaire	571	1,672	1,203	7,581	198	1,070	134	702	13	26	(5)	7	381	728	2,664	3,828
Other Africa, n.e.c.[6]	38	319	6	177					43	29	3	1			6	63
Other	51	753	104	532	4	26	106	257	314	353	938	585	133	53	405	382
Total[6]	8,436	61,808	3,322	34,771	472	2,645	587	3,166	29,570	38,018	32,000	43,901	7,261	7,839	12,677	13,289

[1]Excludes 390,400 carats of crushing bort from Belgium-Luxembourg, Canada, Japan, the Republic of South Africa, and the United Kingdom in 1986, and 251,600 carats from Belgium-Luxembourg, Japan, and the Netherlands in 1987.
[2]Customs value.
[3]TSUS No.
[4]Includes 111,000 carats of synthetic miners' diamonds in 1986.
[5]Less than 1/2 unit.
[6]Data may not add to totals shown because of independent rounding.

Source: Bureau of the Census.

Table 11.—Diamond (natural): World production, by country and type[1]

(Thousand carats)

Country	1983			1984			1985			1986[p]			1987[e]		
	Gem[2]	Industrial	Total	Gem	Industrial	Total	Gem	Industrial	Total	Gem[2]	Industrial	Total	Gem[2]	Industrial	Total
Angola	775	259	1,034	652	250	902	464	250	714	240	10	e250	180	10	190
Australia	7,720	2,480	6,200	3,415	2,277	5,692	4,242	2,828	7,070	13,145	16,066	29,211	r13,650	r16,683	r30,333
Botswana	4,829	5,902	10,731	5,810	7,104	12,914	6,318	6,317	12,635	9,616	3,500	13,110	r9,367	r3,840	r13,207
Brazil	80	450	530	200	550	750	233	217	450	r310	r315	625	320	325	645
Central African Republic	230	65	295	236	101	337	190	87	277	259	99	358	245	105	350
China[e]	200	800	1,000	200	800	1,000	200	800	1,000	200	800	1,000	200	800	1,000
Ghana	34	306	340	35	311	346	r60	r572	632	r50	r510	560	60	540	600
Guinea	23	17	e40	44	3	47	123	9	132	90	14	204	r163	r12	r175
Guyana[e]	5	5	10	6	8	14	4	7	11	3	6	e9	4	7	11
India	12	2	14	13	2	15	14	2	16	r13	2	15	13	2	15
Indonesia[e]	5	22	27	5	22	27	5	22	27	5	22	27	5	25	30
Ivory Coast[4]	NA	NA	NA	r20	r5	r25	r15	r5	r20	r10	r4	r14	15	5	20
Liberia	132	198	330	108	132	240	66	72	138	63	189	252	60	190	250
Namibia	915	48	963	884	46	930	865	45	910	r970	r40	1,010	980	40	r1,020
Sierra Leone	242	103	345	240	105	345	243	106	349	215	100	315	200	100	300
South Africa, Republic of															
Finsch Mine	1,765	3,278	5,043	1,714	3,184	4,898	1,770	3,184	4,954	r1,821	r3,208	5,029	1,455	2,701	r4,156
Premier Mine	800	1,844	2,644	765	1,785	2,550	820	1,864	2,684	r882	r1,977	2,859	772	1,713	r2,485
Other De Beers properties[5]	1,400	569	1,969	1,452	593	2,045	1,500	569	2,069	r1,428	r529	1,957	1,427	546	r1,973
Other	589	66	655	585	65	650	460	35	495	r342	r41	383	409	30	439
Total	4,554	5,757	10,311	4,516	5,627	10,143	4,550	5,652	10,202	r4,473	r5,755	10,228	4,063	4,990	r9,053
Swaziland				7	10	17	9	12	21	17	23	e40	17	23	40
Tanzania	183	78	261	193	84	277	r165	r71	236	r133	r57	190	133	57	190
U.S.S.R.[e]	3,700	7,000	10,700	4,300	6,400	10,700	4,400	6,400	10,800	4,400	6,400	10,800	4,900	7,100	12,000
Venezuela	45	234	279	40	232	272	35	180	215	r45	r189	234	50	200	250
Zaire	3,355	8,627	11,982	5,169	13,290	18,459	r4,032	r16,127	20,159	4,661	18,643	23,304	4,670	18,680	23,350
Total	23,039	32,353	55,392	r26,093	r37,359	r63,452	26,233	39,781	66,014	39,012	52,744	91,756	39,295	53,734	93,029

[e]Estimated. [p]Preliminary. [r]Revised. NA Not available.

[1]Table includes data available through June 3, 1988. Total diamond output (gem plus industrial) for each country is actually reported except where indicated by a footnote to be estimated. In contrast, the detailed separate production data for gem diamond and industrial diamond are Bureau of Mines estimates in the case of every country except Australia (1983-87), Botswana (1987), the Central African Republic (1983-86), Guinea (1984-87), and Liberia (1984-86), for which source publications give details on grade as well as totals. The estimated distribution of total output between gem and industrial diamond is conjectural and, for most countries, is based on the best available data at time of publication.

[2]Includes near-gem and cheap-gem qualities.

[3]Reported figure.

[4]Figures are estimated based on reported exports and do not include smuggled diamonds.

[5]Other De Beers Group output from the Republic of South Africa includes Kimberley Pool, Koffiefontein Mine, and the Namaqualand Mines.

MANUFACTURED ABRASIVES

Manufactured abrasives production experienced a mixed year. For silicon carbide, the quantity and value increased; for fused aluminum oxide, the quantity decreased and value increased; and for metallic abrasives, the quantity and the value increased. In the aggregate, production was essentially unchanged in quantity, but the value increased 5%.

At yearend, four firms were producing fused aluminum oxide at eight plants in the United States and Canada. Production was at 61% of furnace capacity. Reported production of high-purity material increased 31% in quantity and 25% in value compared with that of 1986. Production of regular material decreased 8% in quantity but increased 9% in value to 124,174 tons and $47.4 million. Almost all of the combined output of high purity and regular material was for abrasive applications. One firm reported shipping a quantity of regular material for refractory manufacture. Reported yearend stocks totaled 5,822 tons, a decrease of 72% compared with that of 1986.

One firm produced fused alumina-zirconia in two plants, one each in the United States and Canada. All production was used for abrasive applications. Output increased in both tonnage and value compared with that of 1986.

At yearend, four firms were producing silicon carbide in six plants in the United States and Canada. The companies produced crude material for abrasives, refractories, metallurgical uses, and other applications. Total production was 87% of furnace capacity. Output and value during the year increased slightly to 125,000 tons and $48.8 million. Abrasive use accounted for about 44% of the output, metallurgical use accounted for 55% of output, and refractory and other uses were 1%. Yearend stocks totaled 13,644 tons, a decrease of 25% compared with that of 1986. Cold Spring Granite Co., Cold Spring, MN, and Northern Recovery Systems Inc., Barre, VT, both recovered silicon carbide from the stone cutting industry. The recovered silicon carbide was sold for metallurgical and refractory uses.

The National Defense Stockpile, as of December 31, 1987, contained 249,867 tons of crude fused aluminum oxide and 50,786 tons of abrasive grain-fused aluminum oxide. The crude and grain-fused aluminum oxide was being held as an offset against 379,253 tons of bauxite abrasive grain objective. Silicon carbide stocks were 72,950 tons, and the goal was 29,000 tons.

Metallic abrasives were produced by 11 firms in 12 plants in the United States. Steel shot and grit comprised 92% of the total quantity and 90% of the total value of metallic abrasives sold or used; the balance included chilled iron shot and grit, annealed iron shot and grit, cut wire shot, and steel shot and grit reclaimed by a primary producer. The following six States, in decreasing order of quantity, supplied 100% of the total sold or used steel shot and grit: Michigan, Ohio, Pennsylvania, Virginia, Maryland, and Indiana.

Chilled and annealed iron shot and grit was produced by two companies, one each in Indiana and Ohio. Cut wire shot production was reported by two firms, one in Michigan and one in New York.

WORLD REVIEW

India.—Norton closed one of its two silicon carbide manufacturing facilities and reduced production to 3,000 tons per year at the other plant. Apparently, a power cost escalation of 40% was the reason for the decrease in production. It was more cost effective to import silicon carbide than to manufacture it.[10]

Japan.—Silicon carbide production has been reduced from 115,000 tons per year to an effective capacity of about 50,000 tons per year. Domestic production in 1986 and 1987 was approximately 30,000 tons. It was more economical in 1987 to import silicon carbide, 80% of which was from China, than to manufacture the material domestically.[11]

Norway.—Norton Co. purchased Arendal Smeltewerk A/S of Wydehavn, a major producer of high-quality silicon carbide. The acquisition was made through the purchase of 95% of the foreign-owned shares of Arendal. The Government of Norway, which must approve the sale of Norway-based companies to overseas interests, did not object.[12]

TECHNOLOGY

Silicon carbide ceramic armor, similar to compositions used in kiln furniture, is being used in place of the more expensive boron carbide for armor plating in certain military applications. This includes helicopter armor plating, nose cones of rockets, and

other classified applications.[13]

A British firm began manufacturing large complex silicon carbide shapes for lining equipment subject to highly corrosive and erosive conditions, such as cyclones, micronizer mills, classification equipment, slurry pumps components, and venturis and nozzles.[14]

[1]Physical scientist, Branch of Industrial Minerals.
[2]Industrial Minerals (London). Co. News. No. 240, Sept. 1987, p. 101.
[3]Jewelers' Circular-Keystone. V. 157, No. 5, May 1987, p. 43.
[4]Industrial Minerals (London). World of Minerals. No. 239, Aug. 1987, p. 9.
[5]Mining Journal (London). Development. V. 309, No. 7931, Aug. 21, 1987, p. 141.
[6]Industrial Diamond Review. News. V. 47, No. 523, June 1987.
[7]Indiaqua. Woodworking With PCD tools. No. 48, 3d quarter-1987, p. 106.
[8]Research & Development. Coatings. V. 29, No. 7, July 1987, p. 44.
[9]Industrial Minerals (London). Processing/Equipment. No. 241, Oct. 1987, p. 78.
[10]Dickson, T. Silicon Carbide-Potential in Maturity. Ind. Miner. (London), No. 234, pp. 63-77.
[11]Page 64 of work cited in footnote 10.
[12]Industrial Minerals (London). Filler/Extender. No. 236, p. 42.
[13]Mining Magazine (London). MINPREP 87. Apr. 1987, p. 223.
[14]Work cited in footnote 13.

Table 12.—Crude artificial abrasives manufacturers in 1987

Company	Location	Product
Electro Minerals (Canada) Ltd.	Niagara Falls, Ontario, Canada	Fused aluminum oxide (regular).
Electro Minerals (U.S.) Inc.	Niagara Falls, NY	Fused aluminum oxide (high-purity).
The Exolon-ESK Co.	Hennepin, IL	Silicon carbide.
Do.	Thorold, Ontario, Canada	Fused aluminum oxide (regular) and silicon carbide.
General Abrasives, a division of Dresser Industries Inc.	Niagara Falls, NY	Fused aluminum oxide (regular and high-purity).
Do.	Niagara Falls, Ontario, Canada	Fused aluminum oxide (regular) and silicon carbide.
Norton Co.	Huntsville, AL	Fused aluminum oxide (high-purity) and aluminum-zirconium oxide.
Do.	Worcester, MA	General abrasive processing.
Do.	Cap-de-la-Madeleine, Quebec, Canada	Silicon carbide.
Do.	Chippewa, Ontario, Canada	Fused aluminum oxide (regular and high-purity) and aluminum-zirconium oxide.
Do.	Shawinigan, Quebec, Canada	Silicon carbide.
Superior Graphite Co.	Hopkinsville, KY	Do.
Washington Mills Abrasives Co.	Niagara Falls, Ontario, Canada	Fused aluminum oxide (regular).

Table 13.—Producers[1] of metallic abrasives in 1987

Company	Location	Product (shot and/or grit)
Abrasive Materials Inc.	Hillsdale, MI	Cut wire, steel.
Chesapeake Specialty Products	Baltimore, MD	Steel.
Durasteel Co.	Pittsburgh, PA	Do.
Ervin Industries Inc.	Adrian, MI	Do.
Do.	Butler, PA	Do.
Globe Steel Abrasives Co.	Mansfield, OH	Do.
Metaltec Steel Abrasives Co.	Canton, MI	Do.
National Metal Abrasive Co.	Wadsworth, OH	Do.
The Pangborn Co.	Butler, PA	Do.
Pellets Inc.	Tonawanda, NY	Cut wire.
Steel Abrasives Inc.	Fairfield, OH	Chilled iron.
U.S. Abrasives Inc.	Tippecanoe, IN	Chilled and annealed iron and steel.
Wheelabrator-Frye Inc.	Bedford, VA	Steel.

[1]Excludes secondary (salvage) producers.

Table 14.—Crude manufactured abrasives produced in the United States and Canada, by kind

(Thousand short tons and thousand dollars)

Kind	1983	1984	1985	1986	1987
Silicon carbide[1]	109	137	113	124	125
Value	$52,016	$57,125	$42,563	$48,064	$48,790
Aluminum oxide (abrasive grade)[1]	137	177	169	151	144
Value	$50,565	$63,818	$54,061	$50,584	$56,393
Aluminum-zirconium oxide	W	W	W	W	W
Value	W	W	W	W	W
Metallic abrasives[2]	172	217	197	208	217
Value	$64,849	$82,288	$75,349	$75,210	$76,856
Total[3]	418	531	479	483	486
Total value[3]	167,430	203,231	[4]171,974	173,858	182,039

W Withheld to avoid disclosing company proprietary data.
[1]Figures include material used for refractories and other nonabrasive purposes.
[2]Shipments for U.S. plants only.
[3]Excludes U.S. and Canadian production and value of aluminum-zirconium oxide.
[4]Data do not add to total shown because of independent rounding.

Table 15.—End uses of crude silicon carbide and aluminum oxide (abrasive grade) in the United States and Canada, as reported by producers

Use	1986			1987		
	Quantity (short tons)	Value (thousands)	Yearend stocks (short tons)	Quantity (short tons)	Value (thousands)	Yearend stocks (short tons)
SILICON CARBIDE						
Abrasives	47,248	$19,973	9,858	54,589	$23,128	9,127
Metallurgical	63,293	22,719	5,545	69,109	25,049	4,298
Refractories and other	13,407	5,372	2,743	1,302	613	219
Total	123,948	48,064	18,146	125,010	48,790	13,644
ALUMINUM OXIDE						
Regular: Abrasives plus refractories[1]	135,301	43,347	18,961	124,174	47,354	5,560
High purity	15,251	7,237	2,058	19,946	9,039	262
Total	150,552	50,584	21,019	144,120	56,393	5,822

[1]Abrasives combined with refractories to avoid disclosing company proprietary data.

Table 16.—Production, shipments, and annual capacities of metallic abrasives in the United States, by product[1]

Product	Production		Shipments		Annual capacity[2] (short tons)
	Quantity (short tons)	Value (thousands)	Quantity (short tons)	Value (thousands)	
1986:					
Chilled iron shot and grit	W	W	W	W	W
Annealed iron shot and grit	W	W	W	W	W
Steel shot and grit	184,416	$59,654	192,457	$67,505	277,600
Other[3]	14,718	6,023	15,903	7,705	18,100
Total	199,134	65,677	208,360	75,210	XX
1987:					
Chilled iron shot and grit	W	W	W	W	W
Annealed iron shot and grit	W	W	W	W	W
Steel shot and grit	200,255	56,371	198,743	68,885	253,800
Other[3]	18,470	62,410	18,569	7,971	XX
Total	218,725	118,781	217,312	76,856	XX

W Withheld to avoid disclosing company proprietary data; included with "Other." XX Not applicable.
[1]Excludes secondary (recycle) producers.
[2]Total quantity of the various types of metallic abrasives that a plant could have produced during the year, working three 8-hour shifts per day, 7 days per week, allowing for usual interruptions, and assuming adequate fuel, labor, and transportation.
[3]Includes cut wire, aluminum, stainless steel shot, and data indicated by symbol W.

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